

3.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA.

Series X.

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(1)—ALMANDINE, MARVEL LOCH, Cen.

The recent detailed geological survey of the South Yilgarn area, and the keenness displayed in mineralogical problems by the field staff, has enabled the writer to examine in detail four specimens of almandine from different matrices in the one small area. For the specimens described he is indebted to the Government Geologist, Mr. F. G. Forman, and Mr. H. A. Ellis.

The rock mass in the vicinity of the gold mining centre of Marvel Loch is a Precambrian complex of highly tilted and foliated sediments with metamorphic greenstones, both interbedded and intrusive, and occasional pegmatite veins. There are granite outcrops a few miles distant both to north-east and south-west (1) (2). Almandine occurs freely in bands of metasediments, greenstones and pegmatites.

The workings of the Mountain Queen G.M. are in more or less graphitic mica schist, including some bands in which andalusite is plentiful, and others thickly seeded with garnets. The latter are invariably well crystallised in rhombic dodecahedra, usually quite symmetrically developed, but not uncommonly distorted by elongation along a crystallographic axis, or in other cases along the axis of the zone [022]. The diameter is commonly 3 to 4 mm. The crystals are usually black and almost opaque, probably from minute inclusions of graphite, but in some cases have a translucency of 1 to 2 mm. with a brownish red colour. Several carefully selected uncontaminated crystals from the 280ft. level were analysed with the results given in Col. 1. They prove the mineral to be a manganiferous almandine.

On the east side of Agricultural Loc. 405 there is another bed of dark grey graphitic mica-schist carrying about 5 per cent. of reddish brown almandine in 1 to 3 mm. rhombic dodecahedra. The composition of this is given in Col. (2), showing it to be a magnesian almandine, differing considerably in composition from that first described, though taken from a similar matrix.

Close to No. 2 is an almost black garnetiferous hornblende schist, probably a metasomatic eclogite, which carries many precisely similar looking garnets, forming in the specimens examined about 30 per cent. of the whole rock. The cleanest concentrate that could be obtained for analysis was still contaminated with about 4 per cent. of feldspar and hornblende. The composition of this concentrate is given in Col. 3. The principal subsidiary molecule present is spessartite, as in No. 1, but the pyrope, grossularite and andradite molecules are also prominent.

Finally in the Comet G.M. there is a fine grained quartz-albite-microcline pegmatite, carrying a little muscovite, and thickly studded with small red grains of garnet, mostly 1 mm. or less in diameter. These were concentrated by vanning and then with heavy solutions, and finally analysed with the results given in Col. 4.

A comparison of the proportions of the different isomorphous molecules in the four garnets, reveals by far the greatest proportion of spessartite in that occurring in the pegmatite vein. This is in keeping with experience elsewhere, most pegmatite garnets being either manganiferous almandines or spessartites. Of the two garnets found in metasediments, the chief associate of the almandine molecule is spessartite in one case, pyrope in the other, a difference which must be due to differences in composition of the original sediments. The garnet from the schistose amphibolite contains almost equal proportions of spessartite, pyrope, grossularite and andradite co-crystallised with the preponderating almandine, corresponding to the wider range of metallic oxides available for garnet building in the original basic igneous rock. In only one case, viz., that from the pegmatite, was any of the skiaegite molecule present.

References : (1) 1915, T. Blatchford, Geol. Surv. Bull. 63, pp. 3-64.

(2) 1937, H. A. Ellis, W.A. Mining and Commercial Review, Apr., pp. 52-4.

Analyses of Almandine, Marvel Loch.

No. ...	...	...	1	2	3	4
Matrix	...	...	Mica schist.	Mica schist.	Amphibolite.	Pegmatite.
SiO ₂	...	...	36.22	36.44	39.44	36.20
TiO ₂	...	...	.08	.72	1.04	n.d.
Al ₂ O ₃	...	...	20.38	21.70	19.08	20.76
Fe ₂ O ₃	...	...	3.26	.61	2.05	1.08
FeO	...	...	27.57	32.89	27.90	27.19
MnO	...	...	6.40	.49	3.91	13.34
MgO	...	...	1.93	4.03	1.72	1.22
CaO	...	...	4.40	2.08	4.34	.56
H ₂ O+	...	...	Nil	.87	n.d.	Nil
			100.24	99.83	99.48	100.30
G. ...	...	...	4.17	4.16	4.15	4.20
Analyst	...	...	E. S. Simpson	H. P. Rowledge	H. P. Rowledge	H. P. Rowledge.

Molecules per cent.

Alm.	...	...	64	77	67	61.5
Sps	...	...	15	1	10	30.5
Pyr	...	...	8	16	8	5
Grs.	...	...	4	4.5	8	Nil.
And	...	...	9	1.5	7	1.5
Ski	...	...	Nil	Nil	Nil	1.5

(2)—ANTHOPHYLLITE, MT. PALMER AND MARVEL LOCH, Cen.

Anthophyllite and kuppferite are two rare members of the amphibole group differing from one another only in crystalline form, the former being orthorhombic, the latter monoclinic. Both are characterised by an absence of calcium and sodium, and a preponderance of magnesium over iron, the common formula being $H_2(Mg,Fe)_7Si_8O_{24}$. The practical distinction between them is not easy as the following table shows:—

	Anthophyllite.	Kupfferite.
Composition ...	$H_2(Mg,Fe)_7Si_8O_{24}$	$H_2(Mg,Fe)_7Si_8O_{24}$
Crystal Group ...	Orthorhombic	Monoclinic
Sp. Gr.* ...	3.0	3.05
Hardness ...	5½	5½
Ref. Indices *	1.610, .601, .590	1.615, .603, .590
Elongation (optical) ...	+	+
Extinction, c \wedge Z ...	0° on every prism face	0° (100) to 20° \pm (010)

*Increase with iron content.

The only important distinction of assistance in practical determination is the oblique extinction of kupfferite on all faces in the prism zone except a(100).

The occurrence of several dykes of an almost pure anthophyllite rock in the South Yilgarn goldfield is of unusual interest, because of its rarity. My attention was first drawn to these unusual looking rocks by Mr. H. A. Ellis, of the Geological Survey, who kindly supplied me with typical specimens for determination and with the permission of the Government Geologist placed his field observations at my disposal.

The Archæan complex from Southern Cross southwards beyond Marvel Loch is made up of alternating belts of rock predominantly sedimentary and predominantly igneous (granite and greenstone). The anthophyllite rock appears in several long narrow parallel dykes in three greenstone belts. Further to the east, between Mt. Palmer and Meiers Find, is another small outcrop of similar rock.

Two specimens of this rock type have been analysed. No. (1) is from N.E. of the May Queen G.M.L. 3459, four miles N.N.W. of Marvel Loch, and is slightly weathered. No. (2) is from 3½ miles S. of Mt. Palmer, and is practically fresh. The analytical results obtained are shown in the accompanying table with those of several other rocks of similar composition.

As rocks there are several unusual features to note in them, viz.:

(a) The unusually low proportions of alumina, lime and alkalis amongst the major constituents; and of phosphorus, sulphur and titanium amongst the minor.

(b) The preponderance of magnesia over all other common bases, and of chromium over other minor elements.

These features are characteristic of the hypersthenites, peridotites, serpentines and talc schists, to one or more of which the rock must therefore be related. In looking for other Western Australian rocks of similar composition it was found that the serpentines invariably had a much lower silica percentage, viz. 37 to 42. Even when allowance is made for the extra water in the serpentines, and a comparison is made on the basis of equal water content, the silica in the serpentines is only raised to 40 to 45 per cent., as against 52 to 58 in the anthophyllite rocks. On the other

hand, there is a close resemblance as shown in the table to a hypersthénite, and to certain talc rocks which have been thought to be derived from hypersthénites. It would appear, therefore, that the South Yilgarn anthophyllite rocks are derived from hypersthénites, either by direct hydration, or in two stages, viz., by hydration to a talc rock, followed by recrystallisation under heat and pressure to an amphibole rock.

In hand specimens the rocks are of an almost uniform neutral grey colour, and appear to be made up almost entirely of equidimensional crystals, 3 to 5 mm. across, of anthophyllite of that colour. Scattered at rare intervals over the fractured surface are green crystals of tremolite of similar size, whilst a lens reveals a rather uniform distribution of small black specks of chromite and magnetite.

Microscope mounts of rock slices and powder show that the apparent coarse grains of anthophyllite are really each composed of an aggregate of almost parallel but slightly undulating and intertwining colourless fibres of extreme fineness, viz., 1 to 4 microns. There are also many small felted bunches of unoriented fibres. In both forms it is impossible to measure a true extinction angle owing to the overlapping and twisting of the fibres. When, however, the rock is reduced to a fine powder, about 95 per cent. of the single fibres give a straight extinction characteristic of anthophyllite. The remaining fibres, as well as some coarse splinters, give extinctions $Z \wedge c$ up to 13° and are almost certainly tremolite. In the rock slides this tremolite is visible as rare, and usually non-fibrous, colourless crystals. The black iron ores chromite and magnetite are scattered irregularly over the slide.

Anthophyllite Rock and Related Rocks, Western Australia.

No.	1	1	2	2	3	4	5	6
	%	Mols.	%	Mols.	%	%	%	%
SiO ₂	57·60	47·63	52·31	43·98	55·27	61·00	57·37	47·44
Al ₂ O ₃	1·90	·94	3·95	1·96	3·67	·68	1·14	6·23
Fe ₂ O ₃	1·56	·50	3·26	1·03	·45	n.d.	·51	·76
FeO	5·45	3·86	5·37	3·77	7·17	6·14	6·52	6·78
MnO	·31	·22	·16	·11	·03	·20	n.d.	n.d.
MgO	26·35	33·21	26·39	33·05	28·36	27·88	26·98	26·68
CaO	1·60	1·42	3·17	2·85	2·93	Nil	·53	3·39
Na ₂ O	·01	·03	·12	·10	·86	Tr.	·25	·33
K ₂ O	·04		·06	·03	·18	Tr.	Nil	Tr.
H ₂ O+	4·22	11·91	4·57	12·81	·30	4·72	6·17	5·68
H ₂ O—	·66	—	·70	—	·04	·12	·87	·78
TiO ₂	·09	·06	·23	·15	·16	·01	n.d.	·20
Cr ₂ O ₃	·57	·19	·31	·10	·46	·01	n.d.	·22
P ₂ O ₅	Nil	—	Nil	—	Tr.	·10	n.d.	Tr.
CO ₂	Nil	—	·05	·06	Nil	Nil	Tr.	2·06
FeS ₂	·07	·03	Nil	—	·17	n.d.	n.d.	n.d.
G	100·43	100·00	100·65	100·00	100·05	100·86	100·34	100·55
	2·81	...	2·94	...	3·25	2·83	2·82	2·82
	(approx.)							

Analyst H. P. Rowledge. C. R. Le Mesurier. C. C. Williams. E. S. Simpson. A. J. Robertson. E. S. Simpson.

(1) Anthophyllite rock, near May Queen, G.M., Marvel Loch.

(2) Anthophyllite rock, $3\frac{1}{2}$ miles S. of Mt. Palmer.

(3) Hypersthénite, Norseman, G.S.M. 5646.

(4) Talc Schist, Mt. Taylor.

(5) Talc rock, Meekatharra. G.S.M. 11579.

(6) Talc-chlorite rock, Kalgoorlie. G.S.M. 3391.

(3)—CHLORITE, MT. SATIRIST, N.W. AND KALGOORLIE, CEN.

In my last Contribution (1) emphasis was laid on the paucity of mineralogical data regarding West Australian chlorites, and this was remedied to some extent by a description of three specimens from different places. Data are now available regarding two further ones.

Daphnite, Mt. Satirist, N.W.

In the ridges six miles S. of this hill, masses of microscaly greenish black chlorite have been obtained. These are sufficiently dense and tough to be sawn and polished into trinkets. As a little vitreous quartz is intergrown with the chlorite, it appears probable that the specimens have come from a vein or segregation in the local Precambrian greenstone. The composition of carefully selected material is:—

Daphnite, Mt. Satirist.

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O
21.17	20.02	9.88	33.48	.45	3.10	.10	.06	.12
H ₂ O+	H ₂ O—	TiO ₂	Total	G	Ng = Nm	Np		
10.63	.57	.07	99.65	3.18	1.684	1.681		

Analyst, C. R. Le Mesurier.

The mineral molecules present are:

Daphnite	Cronstedtite	Antigorite	Amesite
65.1	23.2	6.0	5.7 per cent of total molecules.

After calculating these molecules, there remained 3.31 per cent. by weight of silica, probably present as intergrown quartz or opal, and 0.91 per cent. of excess water mostly adsorbed.

By these figures the mineral is shown to be the aphrosiderite variety of daphnite, a variety best defined as that which contains about 20 per cent. of the cronstedtite molecule. The type aphrosiderite from Weilburg, Germany, has the molecular composition Daphnite 71.6, Cronstedtite 11.8, Amesite 11.1, Antigorite 5.5. The Mt. Satirist mineral is greenish black in mass, with the following pleochroism under the microscope; X, very pale yellow; Y = Z, rich green, with slightly bluish tinge. The mineral is optically negative with Ng = Nm 1.684, and birefringence very weak making Np 1.681. The considerable increase in N over the normal (Nm 1.651) with increase in Fe₂O₃ from 5.18 (Weilburg) to 9.88 (Mt. Satirist) is notable, and in accordance with experience.

Daphnite, Kalgoorlie.

From small cavities in a quartz vein crossing the Lake View lode in the Perseverance G.M. some beautiful specimens of a greenish black vermiform chlorite were collected by G. S. Compton in 1935. The bundles of crystals resemble a confused mass of intertwined worms of uniform diameter (about 1.5 mm.), implanted on quartz and ankerite, and in turn occasionally supporting isolated crystals of ankerite. Cross sections of the rods reveal a rosette of small plates, radiating from the centre at right angles to the sur-

face and to the axis of the rods. The composition of this chlorite is as follows:—

<i>Daphnite, Kalgoorlie.</i>								
SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O
23.32	17.45	4.09	38.90	.01	4.54	.24	Nil	Trace
H ₂ O+	H ₂ O—	TiO ₂	Total	G	Ng	Np		
10.89	.80	.03	100.27	3.10	1.662	1.659		
Analyst, C. R. Le Mesurier.								

The mineral molecules present are:

Daphnite	Ferantigorite	Antigorite	Cronstedtite	
60.0	17.3	13.7	9.0	per cent of total molecules.

Excesses of 0.89 per cent. of SiO₂, and 0.59 of H₂O are indicated by the analysis, and are probably extraneous to the chlorite. This mineral is practically identical in composition with the type metachlorite variety of daphnite found at Elbingerode in Germany (2).

The following optical data were determined under the microscope:—

X = c, pale yellow; Y = Z, rich bottle green.

Ng = Nm, 1.662, Ng — Np, small, about .003. Optical sign, negative.

In similar cavities between the 1,300 and 1,700 feet levels of the same lode in the same mine, there are dense, friable masses of a greenish black chlorite, which has similar optical properties to the above, the colour scheme being the same, and Ng = Nm, 1.657; Np, 1.655. It has almost the same specific gravity, viz., 3.15, and iron content, viz., FeO 38.22, Fe₂O₃ 2.93 per cent. Sifted specimens of this chlorite were found to contain a considerable proportion of micro-vermiform particles, with prism diameters from 0.02 to 0.20 mm.

This chlorite is evidently one of the latest minerals to develop in the lode channel.

References: (1) 1936, E. S. Simpson, Jour. Roy. Soc., W.A., 22, p. 2, 3.

(2) 1896, Dana, System VI., p. 656.

(4)—CHLORITOID, MT. MAGNET, MUR.

Chloritoid has already been recorded from two places in the State, viz., in an altered sediment (mica schist) at Collier Bay, 18 miles E.S.E. of Yampi Sound, and in a series of metasomatic dolerites at Kalgoorlie. In 1935 several deep bores were put down in the Precambrian complex on the Hill 60 G.M.L. of the Mt. Magnet Gold Mines, and in the cores from two of them R. W. Fletcher recognised chloritoid. In the No. 1 Bore four different bands of chloritoid rock were recognised, in each of them the mineral being in minute discs, usually well under one millimetre in diameter, set in a ground mass of quartz, sericite, and chlorite.

A similar rock met with at 542 feet in the No. 3 Bore has been analysed for me by Mr. C. R. Le Mesurier. The results he obtained were as follow:—

<i>Chloritoid Mica-schist, Mt. Magnet.</i>								
SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O
66.68	20.21	.37	2.46	.01	.54	.31	1.07	4.18
H ₂ O+	H ₂ O—	TiO ₂	CO ₂	P ₂ O ₅	FeS ₂	Total	G	
2.97	.10	.92	.17	.22	.04	100.25	2.76	

The rock is grey in colour with appreciable schistosity. On the fractured surfaces many minute black specks are visible, which prove under the microscope to be discs of chloritoid from 0.2 to 0.5 mm. in diameter. By calculation they form approximately 8 per cent. of the whole rock, finely granular quartz and scaly sericite each forming about 40 per cent. The other minor constituents are chlorite, rutile, and apatite. The rock is plainly a metamorphic sediment. Of the three known varieties of chloritoid, the normal variety, the magnesian (sismondine) and the manganiferous (ottrelite), the last cannot be that present, since manganese is practically absent from the rock. The poor intensity of colour in the sectioned mineral and the molecular ratio of FeO to MgO in the whole rock, viz., 2.6 to 1.0, points to the mineral being sismondine. Its form is typical, the basal planes being sharply defined, whilst the prism faces are as usual absent and replaced by ragged edges. There are innumerable dusty inclusions of quartz, etc., in each crystal.

(5)—COLUMBITE AND MANGANOCOLUMBITE, McPHEE'S RANGE, N.W.

McPhee's Range is an area of Precambrian greenstone projecting from the granite plain of the Turner River, and lying about 20 miles to the east of Wodgina. First known as an auriferous area of no great importance, it has for many years past been chiefly noted for its alluvial and lode deposits of commercial tantalum ore, first discovered and worked by Bonnor in 1905. This has consisted mainly of manganotantalite, but has included also a little ferrotantalite, tapiolite, and microlite. A considerable quantity of manganocolumbite has been found there, much of it very beautifully crystallised. Ferrocolumbite is comparatively rare. The last two minerals, rich in niobium, have been valueless in the past, but are now in considerable demand.

The greenstone of the range, as well as the granite immediately to the west of it, is traversed by a large number of pegmatites characterised by a preponderance of albite and quartz, and genetically connected with the granite. A small amount of tantalum and niobium ore has been obtained from the "lodes," which are albite pegmatite veins, mainly in the greenstone country, but also to a less extent in the granite. The main part of the ore won in the past has, however, been found in the alluvium derived from the pegmatites.

The four compounds FeTa_2O_6 , MnTa_2O_6 , FeNb_2O_6 and MnNb_2O_6 are completely isomorphous and are found in nature co-crystallised to an infinitely varied extent. It is evident from the examination of commercial parcels of ore and prospectors' samples, that the tantaliferous minerals at McPhee's Range, whilst predominantly rich in manganese as base, vary greatly in the relative proportions of tantalum and niobium, even at times in the various pebbles constituting a single sample. This is very noticeable in alluvial ore derived from the disintegration of more than one pegmatite vein. There is very little evidence available regarding the uniformity or otherwise of the ores in a single vein, but in one at least the Ta and Nb contents cover a wide range. There is practically no evidence of the stage of pegmatite development at which they were deposited, but the frequent perfect crystallisation would suggest an early stage.

The percentages by weight of Ta_2O_5 and Nb_2O_5 in a mineral of the tantalite group are hyperbolic functions of the specific gravity of the crystal.*

For example—

$$\text{Ta}_2\text{O}_5 \text{ per cent.} = 251.6 - \frac{1308.5}{G}$$

This follows from the specific gravities of pure tantalite (7.90) and pure columbite (5.20), and their identical molecular volumes in the crystalline state. A graph showing the relations between these two factors is reproduced in Plate 1. It has been repeatedly checked in the Government Laboratory against analyses of actual crystals. The difference in molecular weight between the corresponding iron and manganese compounds is so slight, that the curves for the two series FeTa_2O_6 — FeNb_2O_6 and MnTa_2O_6 — MnNb_2O_6 are practically coincident.

The specific gravity being an easily determined factor, the graph can be used as a means of determining rapidly and closely the composition of a crystal or pebble of a mineral of this series in respect of the metallic acids. For many years it has been so used with great advantage in the Government Laboratory in Perth. It has been calculated that the mineral with equal molecules of FeTa_2O_6 and FeNb_2O_6 , or of MnTa_2O_6 and MnNb_2O_6 , has a specific gravity of 6.55. As the tantalum compounds are the heavier it follows that all fragments of mineral with G over 6.55 are properly classified as tantalite or manganotantalite, and those with G under 6.55 as columbite or manganocolumbite. In the past only tantalites have been in commercial demand; the tantalum being utilised and the niobium wasted. Recently, however, a use has been found for niobium in the steel industry, and consequently a demand for columbites with a high percentage of niobium has arisen.

The richest tantalum ores found in McPhee's Range have been nearly pure MnTa_2O_6 with G 7.80 and 7.74. These came from workings one mile N. of M.C. 80 and from Thelemann's claim at Pilgangoora.

The richest niobium ores, judged by the specific gravities, were ones having G 5.21, 5.35 and 5.42, representing 99.5, 94.2 and 88.4 per cent. by weight of $(\text{Mn}, \text{Fe})\text{Nb}_2\text{O}_6$ or 78.3, 74.2 and 69.6 per cent. of Nb_2O_5 . The first of these was a recent specimen from 2 miles N. of M.C. 80, the other two were amongst the earliest specimens from Bell's and Macbeth's claims "near Green's Well."

Examples of parcels of ore from here with a narrow range of specific gravity, and therefore a fairly uniform ratio of Ta to Nb are as follow:

No.	Locality.	G Range	Nb_2O_5 %	G Mean.	Nb_2O_5 Mean %	Ta_2O_5 Mean %	FeO %
1.	5m. N. of Green's Tank	6.18-6.47	42.5-32.3	6.33 (M/8)	38.0	44.6	3.53
2.	Pilgangoora	5.90-6.04	51.8-47.0	6.01 (M/7)	47.8	33.8	5.80
3.	Do.	5.77-5.31	53.5-38.5	5.98 (M/17)	49.0	32.4	6.39
4.	Hooley's M.L. Pilgangoora	5.58-5.79	63.0-55.5	5.70 (M/4)	58.8	21.6	15.99

The first three of these consist of manganocolumbite; No. 4 is columbite (ferrocolumbite).

* This law of course holds good in regard to the components of all isomorphous series with two variables, e.g., ferberite-huebnerite, mimetite-pyromorphite, spinel-hercynite, etc. The general formula is:—

$$H\% = \frac{100 G_H(G_M - G_L)}{G_M(G_H - G_L)}$$

Where H is the heavier component, e.g., FeTa_2O_6 , G_H , G_L and G_M are the specific gravities respectively of the heavier component, the lighter component and the mineral under experiment. The percentage of FeTa_2O_6 multiplied by $\text{Ta}_2\text{O}_5/\text{FeTa}_2\text{O}_6$, i.e., by 0.860, gives the percentage of Ta_2O_5 .

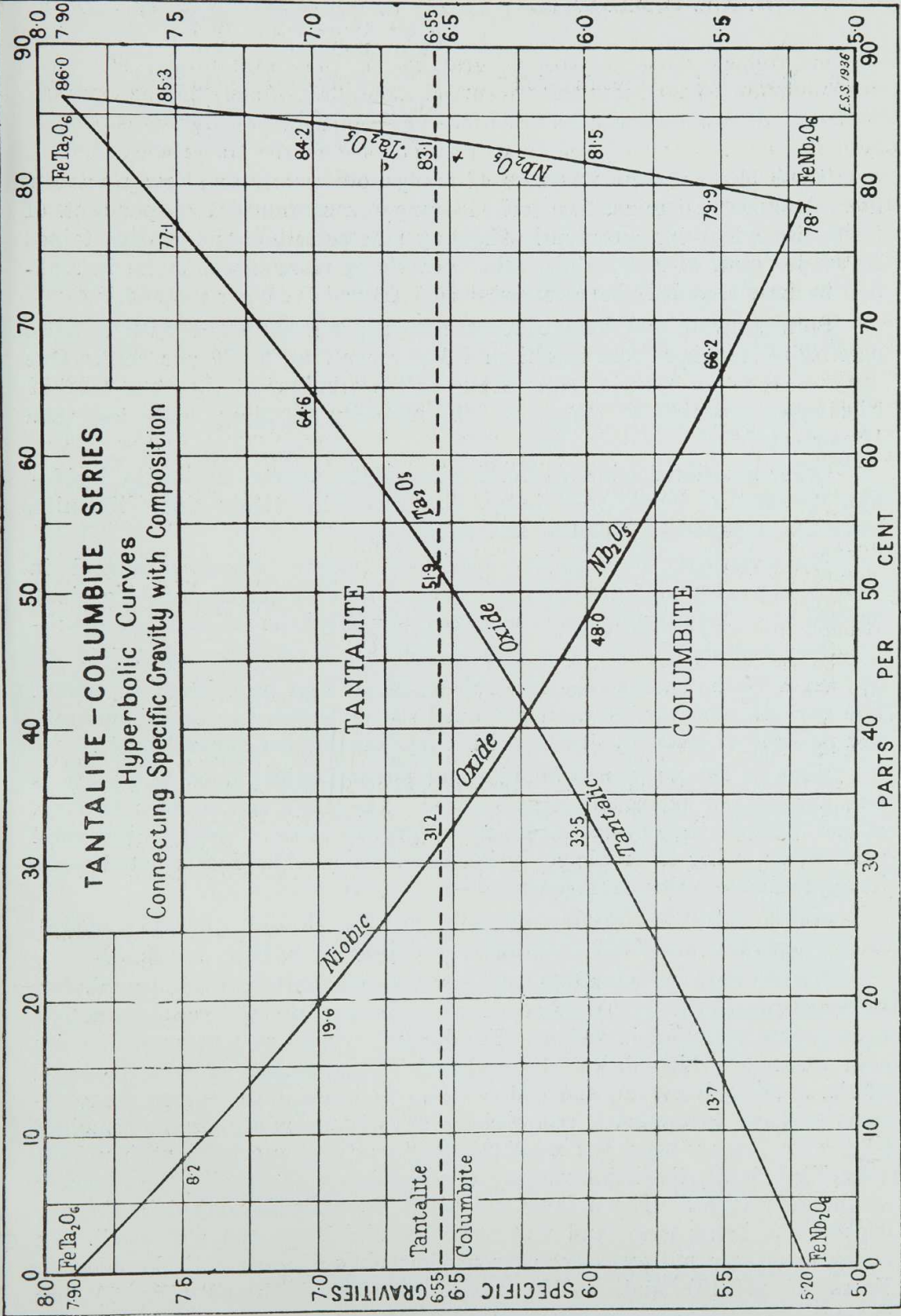


Plate 1.

Two examples of a wide range of grade in the pebbles of one parcel are worth quoting:—

No.	Locality.	Range.	Mean.	FeO
5.	1½ m. N.E. of M.L. 80 ...	G 6.05–7.69 Nb ₂ O ₅ 46.5–4.2 Ta ₂ O ₅ 35.3–81.5	6.73 (M/7) 26.7 57.0	3.38
6.	Bell's M.L. "Green's Well" ...	G 7.35–6.84 Nb ₂ O ₅ 72.2–23.9 Ta ₂ O ₅ 7.1–60.0	6.45 (M/8) 34.2 48.7	< MnO

These obviously are mixtures of manganocolumbite and manganotantalite. Another similar mixture from Pilgangoora contained 1.69 per cent. of FeO, with a high MnO content. The only true columbite analysed contained 15.99 per cent. of FeO, whilst other parcels of manganocolumbite in addition to those recorded above carried only 3.26 and 5.22 per cent. of FeO.

Both alluvial and lode concentrates are contaminated with a little cassiterite, ranging from less than 0.5 per cent. up to 20 per cent. One very exceptional sample, from Houston's workings on the east side of Pilgangoora, carried 40 per cent. The majority, however, carry less than 10 per cent.

Other associated minerals noted were albite, quartz, muscovite, lepidolite, spessartite, beryl, spodumene, kaolin, calcite (travertine), limonite, hæmatite, magnetite, tapiolite and microlite.

The fragments of columbite examined (mostly alluvial) ranged in weight from about 165 grammes (6 ozs.) down to 0.1 grammes (1½ grains) or even less. A fairly typical alluvial parcel yielded the following grades:—

Over 4 mesh, 11.6%. Over 10 mesh, 80.7%. Under 10 mesh, 7.7%.

On a fresh fracture the mineral is opaque and pure black in colour. The surface, however, is usually stained red or brown by ferruginous soil, and possibly at times by decomposition products of the mineral itself.

Much of the manganocolumbite and ferrocolumbite from this place is well crystallised but usually single ended. The lower end is often missing, either through the crystal being an outgrowth from a pre-existing solid surface, or owing to breakage during denudation. The forms noted were, in approximate order of frequency:—

a(100) b(010) c(001) u(133) m(110) k(103) e(021) y(210)
g(130) z(530) q(023) f(102) n(163) o(111).

The crystals of columbite and manganocolumbite are either tabular, flattened parallel to (100), or columnar, and vary in size from 0.1 gramme up to many grammes in weight. The largest crystal of manganocolumbite seen was much chipped, but still weighed 165 grammes. It was composed of the forms a b c u m, and had G 5.95. The next largest, also fragmentary, weighed 30 grammes, and had G 5.78. Occasionally simple combinations of a b c are seen, but mostly these faces are associated with u(133) (See Figs. 1, 2), the habit varying considerably with varying development of the four forms. The u faces are often unevenly developed in the one crystal u¹u⁴ being large and u²u³ small, or u¹u³ large and u²u⁴ small. In an extreme case u²u³u⁴ were present, but u¹u³u⁴ were entirely missing. Faces of m(110) and y(210) may be moderately broad (Fig. 1), but usually these and other prisms, such as g(130) and z(530), are only narrow chamfers on edges of the pinacoids. e(021) is a fairly common form (Fig. 1) and well developed, but the domes k(103), f(102) and g(023), and the pyramids n(163) and o(111) are rare and poorly developed. In one very

unevenly developed crystal $a^2m^1m^4k^1$ were large, $a^1b^1b^2g^4u^3u^4$ were small, whilst $em^3m^3g^1g^2g^3u^1u^2$ were entirely missing. Tabular twins on $e(021)$ are extremely rare.

Some complex combinations observed were:—

$a \ b \ c \ u \ e \ y \ m \ g$ $a \ b \ c \ u \ n \ e \ k \ y$
 $a \ b \ c \ u \ n \ o \ k \ m$ $a \ b \ c \ u \ n \ f \ e$

Goniometer measurements were made of a crystal of ferrocolumbite with G 5.55. The readings were:—

Face	a^1	z^1	m^1	g^1	b^1	m^2	z^2	a^2
ϕ	$0^\circ 0'$	$26^\circ 35'$	$39^\circ 46'$	$67^\circ 51'$	$90^\circ 0'$	$140^\circ 59'$	$153^\circ 51'$	$180^\circ 0'$
ρ	$90^\circ 0'$	$89^\circ 31'$	$89^\circ 7'$	$90^\circ 0'$	$90^\circ 0'$	$89^\circ 41'$	$89^\circ 41'$	$90^\circ 0'$

Face	z^3	m^3	g^3	b^2	g^4	m^4	z^4	c^1
ϕ	$206^\circ 22'$	$219^\circ 22'$	$247^\circ 36'$	$270^\circ 4'$	$290^\circ 45'$	$320^\circ 40'$	$333^\circ 30'$	...
ρ	$90^\circ 12'$	$90^\circ 34'$	$90^\circ 34'$	$90^\circ 0'$	$90^\circ 0'$	$90^\circ 25'$	$90^\circ 17'$	$0^\circ 0'$

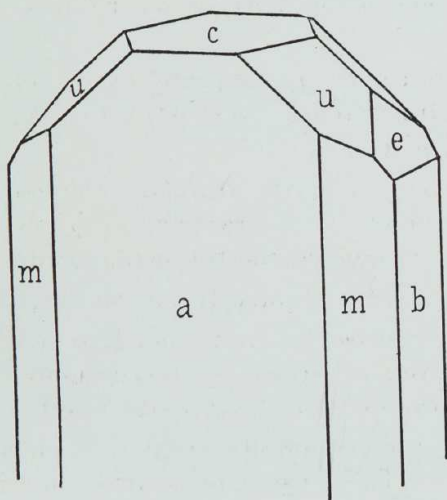


Fig. 1.

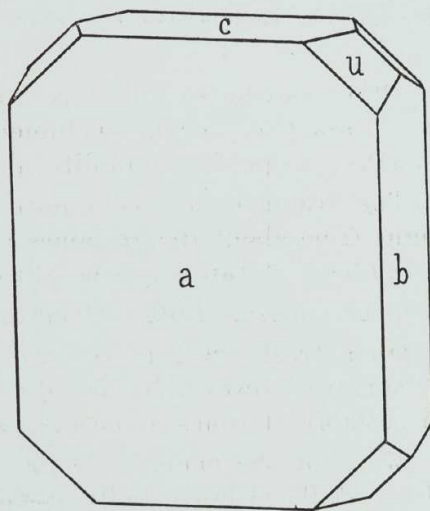


Fig. 2.

Crystals of Manganocolumbite, McPhee's Range.

No sharp reading could be obtained for the forms u and e . From the mean reading for az , the ratio $a : b$ was calculated to be 0.82976.

The (100) faces are not uncommonly complicated by small bas-reliefs of parallel crystals. In other cases this face is striated. [Fan shaped aggregates of tabular crystals were noted, in which the individuals were attached by a face vicinal to (100) whilst all the (010) faces were in two parallel planes. Still rarer were "Mushroom" forms, in which a large number of small prismatic individuals were combined in the form of a conical segment of a sphere. Four of these had G ranging from 6.38 to 6.55.

(6)—DUFRENITE, GINGIN, S.W.

This bright green basic ferric phosphate, $Fe_2(OH)PO_4$, was found in large quantities in the Cretaceous coprolite beds at Dandaragan in 1906. Although similar strata extend southwards to Gingin, the only dufrenite previously found at the latter place was in the form of slight green stains

in boulders of glauconite sandstone, which were collected by the writer in 1926 in a creek bed half a mile S.S.E. of Molecap Hill. Last year Mr. J. E. Wells drew my attention to an important occurrence of the mineral with coprolite at Poison Hill, four miles N. of the town.

Owing to two landslips on the western face of the hill, good fresh sections of about 50ft. of the upper greensand are exposed. A typical section here, illustrated in the Fig. 3, is as follows:—

Top (A) Weathered (partly limonitised) greensand, with rare coprolite	30 ft.
(B) Greensand with many large coprolites	2 to 4 ft.
(C) Fresh greensand mostly impregnated with dufrenite and carrying thin lenses very rich in it	8 ft.
(D) Rich dufrenite band	0.5 to 1 ft.
(E) Glauconitic clay	1 ft.
(F) Greensand with abundant small coprolites	8 ft.

Bottom about 50 to 70 feet above chalk bed.

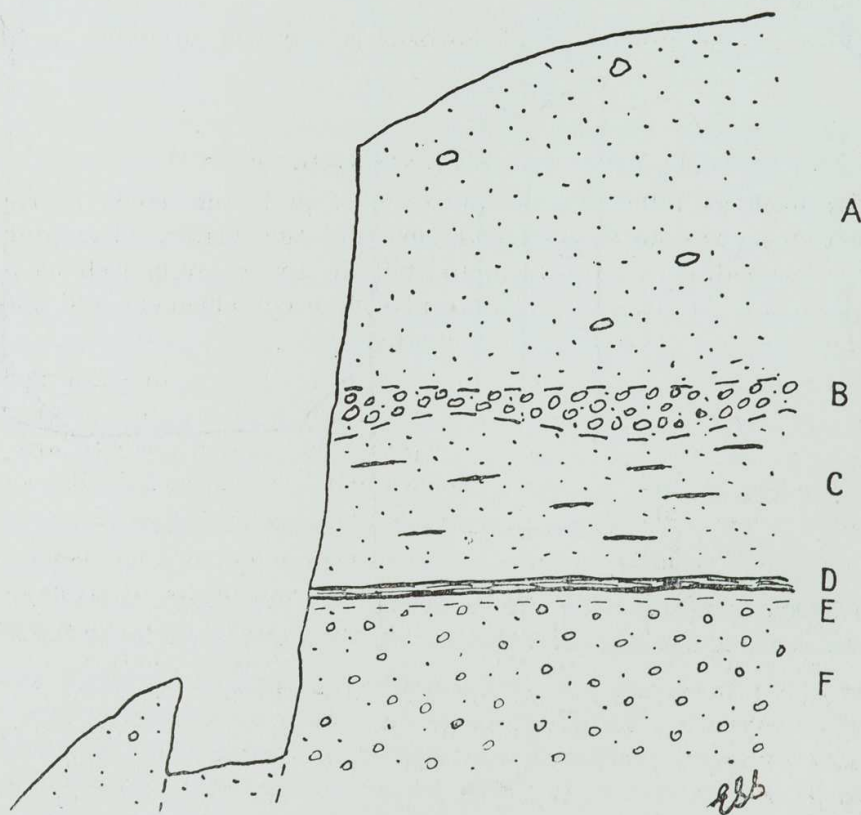


Fig. 3.

Section of Cretaceous Beds west side of Poison Hill, Gingen.

The rich dufrenite horizon (D) is a mixture of dufrenite, glauconite, quartz sand and kaolin, the whole bright green in colour or mottled with brown limonite and iron-stained clay. Immediately beneath it the thin layer of glauconitic clay seems to be almost impervious to water. The lowest coprolitic greensand extends below the ground level at the foot of the cliff. No dufrenite is visible in it.

My impression of the origin of the dufrenite is that the richest bed (D) was originally a layer of clayey greensand with abundant marcasite or pyrite and possibly apatite, concretions. The sulphides were oxidised by air and oxygenated water as the country became eroded, giving rise to solutions of sulphuric acid and iron sulphates. In contact with coprolite, or lime phosphate solutions derived from them, ferrous and ferric phosphates would form, and ultimately be precipitated and fixed in position as diffusions and concretions of the very stable compound dufrenite, the main concentration being immediately above an impervious layer of clay. In support of this theory, whilst the coprolites in some bands are hard and compact, averaging 22.7 per cent. of P_2O_5 , in others they are porous and friable, being evidently leached, and carry only 10.2 per cent. P_2O_5 . Furthermore, a distinct odour of SO_2 emanates from the face of the smaller landslide, indicative of oxidising marcasite or pyrite.

No crystallised mineral is to be seen here, all of it being earthy and massive. Even the apparently purest pieces are heavily impregnated with grains of quartz, glauconite and kaolin, the dufrenite acting as a cement. Some of the richest looking material from horizon (D) was found to contain: Fe_2O_3 23.31, P_2O_5 7.09 per cent. This is equivalent to about 25 per cent. of dufrenite.

The impregnated greensand of horizon (C) would probably average 5 to 10 per cent. of dufrenite.

(7)—ELBAITE, RAVENSTHORPE, S.W.

As far back as 1909 (1), the presence of pink and green tourmaline at Ravensthorpe was noted by L. Glauert and the writer. The pink was obviously the rubellite variety of elbaite, but the green might well have been either that species or dravite. The result of recent chemical and physical investigation has proved that both are elbaite.

The two colour varieties are closely associated with one another in a quartz-microcline-albite pegmatite in Precambrian greenstone a short distance to the north-west of the town. Spodumene and muscovite are abundant in the same vein, whilst rarer constituents are lepidolite, beryl, manganocolumbite, black dravite, and montebrasite.

Although no gem material has been obtained, some very handsome specimens of alkali tourmaline have been collected. Specimens often show only the pink variety in bunches, frequently radiated, of fine (1 to 2 mm.) prisms. In some specimens there is a pronounced crustiform structure, one such having a dense layer of radiating rubellite 10 to 20 mm. thick on one face, then a sharply outlined central band of albite 5 to 10 mm. thick, succeeded in turn by a third layer, 3 to 5 mm. thick, of lepidolite. The colour of the rubellite ranges from "phlox pink" (R. 65f) through "pale rosolane pink" (69'd) to "vinaceous lilac" (69³). The translucency is of a low order, about 1 to 3 mm. The specific gravity is 3.00 to 3.02, refractive indices No. 1.637, Ne. 1.619; and dichroism, E. colourless, O pale pink when over 0.5 mm. thick, colourless in thinner sections. A partial analysis yielded the figures given below.

Closely associated with the rubellite is a green elbaite with G 3.02 to 3.04; refractive indices No. 1.634, Ne 1.619; and dichroism, E colourless, G pale green when over 0.5 mm. thick, colourless in thinner sections. The colour in mass is a series of tints of greyish green which are hard to match, but approach Ridgways 33³, 33³i and lighter tints of the same, with rarely

41³i. Only one crystal showed any high degree of translucency, and this, because of lack of fluid inclusions, and somewhat higher iron content, had G 3.06, and colour olive green. A partial analysis given below showed that the green variety had considerably more iron, manganese and magnesium in it than the pink variety. The figures were:—

Elbaite, Ravensthorpe.

	SiO ₂	Al ₂ O ₃	FeO*	MnO	MgO	CaO	Li ₂ O	Na ₂ O	K ₂ O
Pink	39.07	41.25	.19	.54	.10	.29	1.28	2.32	.20
Green	37.92	39.18	2.14	1.34	.40	.22	1.24	2.64	.42

* Equivalent to total Fe.

In habit both types form hexagonal or curved triangular prisms (a, m), the green ones being stouter, having a diameter of 3 to 10 mm. They occur, in the case of the green, in parallel or unoriented groups with interstitial albite or quartz. In one specimen the mineral is embedded in spodumene.

Green monochrome elbaite is rare at Ravensthorpe, but a layer of the green variety enveloping a core of pink is comparatively common. Stout prisms of rubellite appear in many cases to have grown outwards from the walls of a fissure or from a tabular mass of spodumene, and at an advanced stage in their growth the composition of the precipitating thermal solution has suddenly changed, with the result that a final layer of green elbaite has been deposited on them in parallel position. Such overgrowths of celandine to artemisia or American green (R 33⁴-33^b-33³i) on a core of lilac elbaite make very handsome specimens. The greatest rarity is a core of milk white elbaite covered with the green.

The black dravite occurring occasionally in the same vein has G 3.10 with dichroism E colourless, O cobalt blue.

Reference: (1) 1909, E. S. Simpson and L. Glauert, *Geol. Surv. Bull.* 35, p. 22, 46.

(8)—GAHNITE, GOYAMIN POOL, S.W.

Quartzites are not so prominent amongst the Precambrian metasediments of the Chittering Valley as they are in the same series further north between Moora and Three Springs, or further south about Bullsbrook. In the more common rock type a quartz biotite schist, gahnite has been found at Gillingarra, 45 miles north of here, and been previously described (1). About three-quarters of a mile east of Goyamin Pool is a thin bed of slightly sillimanitic quartzite, interbedded with the prevailing quartz-biotite schists, and close to an intrusive or interbedded amphibolite and garnet amphibolite. In section the quartzite shows small interstitial bunches of microscaly white mica and occasional prisms of sillimanite, apatite and zircon. In hand specimens it is seen to be traversed by a network of small quartz veins carrying grains of green gahnite and pale brown staurolite, both of which have also penetrated the rock on either side to a slight depth. In places they are evenly and sparsely distributed through the vein or rock, in others there are considerable concentrations of gahnite in the veins, forming as much as 50 per cent. of the whole.

The grains of gahnite range from a fraction of a millimetre up to 5 mm. in diameter, the average being a little over one millimetre. The shade of green varies from about R 35⁷i to 35⁷k. The grains are moderately translucent in mass and completely transparent in thin section (about 0.05 mm.) when the colour ranges from colourless to rather strong bluish green.

A number of pieces of rock showing the mineral were crushed and concentrated, first by vanning, then by sinking in methylene iodide solution. The concentrate weighed 14 per cent. of the rock and contained about equal quantities of gahnite and staurolite, the latter in well formed 1 mm. or smaller crystals. By further treatment with Clerici solution (G 4.2) an almost pure concentrate of gahnite was obtained. Examination under the microscope proved the mineral to be vitreous, transparent, green in colour and isotropic, and only contaminated with a little iron stain, quartz and mica. Deducting 0.39 per cent. of Fe_2O_3 soluble in weak HCl and 0.05 of water combined with it, the analytical figures were:—

Al_2O_3	Cr_2O_3	ZnO	FeO	MnO	MgO	CaNi	SiO_2	Total
57.72	Nil	29.46	8.88	.02	2.79	Nil	1.08	99.95

Analyst C. R. Le Mesurier.

The specific gravity was 4.38. The composition of the Goyamin Pool mineral is almost identical with that of the Gillingarra gahnite (1).

Reference: (1) 1930, E. S. Simpson, Jour. Roy. Soc., W.A., 16, p. 30, 31.

(9)—GROSSULARITE, MELVILLE, Mur.; TOODYAY, S.W.; AND MEIER'S FIND, Cen.

Melville, Mur. Reference was made to the occurrence here of two species of garnet, andradite and spessartite, in two previous contributions (1), (2). A third species, grossularite, remains to be described. Garnets, often well crystallised and of fairly large size, up to 2 cm. diameter, are found in several places in the amphibolite area. Analyses and specific gravity determinations indicate that there is a complete series ranging from almost pure andradite, containing only 0.22 per cent. alumina and having G 3.87, to a ferriferous grossularite with 13 per cent. of alumina and G 3.62. A single crystal was found with G 3.60, indicating more alumina still, whilst garnets of intermediate composition had G 3.81, 3.78 (N 1.895), 3.71, 3.69, 3.65. Pure grossularite contains 22.7 per cent. Al_2O_3 and has G 3.55 and N 1.730. Pure andradite, which is fully isomorphous, has no Al_2O_3 but in place of it 31.5 per cent. Fe_2O_3 , with G 3.85 and N 1.900.

On Elliott's gold prospecting area, about one mile north of the town-site, a shear zone in amphibolite traversed by many veinlets of quartz has been exploited for gold. The quartz veins were remarkable for containing a number of beautiful crystals of brown garnet, ranging from 0.5 to 2.0 cm. in diameter. Some of these occurred in single isolated crystals, but more often they were in parallel or unoriented groups. The form is the rhombic dodecahedron d(110) modified by more or less narrow faces of n(211) and s(321). In most cases the faces have a very brilliant lustre; whilst the surface colour of the freshest and brightest is about hessian brown (R 5'm), bleaching of some bring them near snuff brown (R 15"k). Their identity as ferriferous grossularite is proved by their composition given below. The calculated molecular composition per cent. is: grossularite, 58.0; andradite, 36.8; almandine, 4.1. spessartite, 0.9; pyrope, 0.2. In addition there are 3.25 per cent. by weight of included quartz.

Groups of almost equally perfect crystals with G 3.65, 3.69 have been found associated with massive garnet in a quartz reef near the Victoria G.M. 1½ m. N.E. of the Basin, i.e., 3 miles N. of Melville township. These are

slightly darker in colour than the previous ones, and whilst some are almost unmodified dodecahedra, others have very broad faces of $n(211)$, with only narrow bevels of $s(321)$.

The same mineral too, in crystals up to 3 cm. in diameter lacking the form (321) and with only rare faces of (211), has been found half a mile W.N.W. of the townsite. Its G is 3.60.

Grossularite, Melville and Toodyay.

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO
(1) Garnet, Melville	40.08	.58	13.18	11.16	1.74	.34	.06	32.68
(2) Rock, Toodyay	50.68	.96	12.63	3.79	2.13	1.02	1.71	26.81

	Alks.	H ₂ O+	H ₂ O—	Total	G	Analyst.
(1) ... Nil	Trace	Nil	99.82	3.62	D. G. Murray	
(2) ... Trace	.35	.26	100.34	3.27	H. P. Rowledge	

Toodyay, S.W. A garnet hornstone has been found in the Precambrian series a little to the south-east of Key Farm, two miles S. of Toodyay. Its composition is given above, from which the following approximate mineral composition has been deduced:—

Grossularite	Quartz	Diopside	Sphene	Chlorite & Actinolite
68.3	16.8	11.6	2.3?	1.0 per cent. by weight.

The titanium here calculated to sphene may form part of the garnet.

The molecular composition of the garnet is:—

Grossularite	Andradite	Almandine	Spessartite
77	16	4	3 mols. per cent.

The rock is an indistinctly bedded, semivitreous hornstone of a general yellowish green colour, not far from Ridgway's grape green (25^g). Thin short lenses of transparent quartz follow the bedding plane, and there are occasional small splashes of greenish black amphibole and chlorite which are more freely developed on the contact.

A thin section shows that by far the most abundant constituent is colourless garnet in closely compacted crystals and grains, 0.05 to 0.20 mm. in diameter. More or less perfect rhombic dodecahedra are plentiful. The garnet forms broad bands associated with rare prisms of colourless diopside. There is also a little cloudy chlorite and rare actinolite. Between the garnet bands are bands of vitreous quartz, coarsely crystalline. The quartz encloses a little fine dust, and occasional crystals of garnet and diopside are completely embedded in it.

This rock is most probably a highly metamorphosed siliceous and argillaceous limestone.

Meiers Find, Cen.—At this new gold find in South Yilgarn pale pink to pale brown masses of grossularite are plentiful in a quartz vein. With one exception, which yielded a dodecahedral angle of 60°, no crystal forms are visible, the masses having rough boundaries and reaching 2 or 3 cm. in length. There are occasional small intergrowths of a greenish grey amphibole, probably actinolite. The garnet is isotropic, with G 3.55, N 1.740 approximately. A rough analysis of a small fragment gave the following figures:—

SiO₂, 39; Al₂O₃, 25; Fe₂O₃, 0.5; CaO, 34.5; MgO, 1.5.

The mineral is obviously an almost pure grossularite.

References: (1) 1928, E. S. Simpson, Jour. Roy. Soc. W.A., 14, p. 52-3.

(2) 1934, E. S. Simpson, Idem 20, p. 55-6.

(10)—HAEMATITE (HYDROHAEMATITE), INGLEHOPE, S.W.

In recent years the system $\text{Fe}_2\text{O}_3\text{-H}_2\text{O}$ has been subjected to intensive study, one of the objects in view being to solve the constitution of the long series of supposed individual minerals in which the ratio of Fe_2O_3 to H_2O varies from infinity to $1/2$.

The older school of mineralogists treated all the following minerals as independent species:—

(1) Haematite	Fe_2O_3
(2) Hydrohaematite	$\text{Fe}_2\text{O}_3 \cdot \frac{1}{2}$ (or less) H_2O
(3) Turgite	$\text{Fe}_2\text{O}_3 \cdot \frac{1}{2} \text{H}_2\text{O}$
(4) Lepidocrocite	$\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$
(5) Goethite	$\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$
(6) Limonite	$\text{Fe}_2\text{O}_3 \cdot 1\frac{1}{4}$ (\pm) H_2O
(7) Hydrogoethite	$\text{Fe}_2\text{O}_3 \cdot 1\frac{1}{3} \text{H}_2\text{O}$
(8) Xanthosiderite	$\text{Fe}_2\text{O}_3 \cdot 2 \text{H}_2\text{O}$
(9) Limnrite	$\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

The result of the latest investigations, including X-ray examination of minerals and the study of dehydration curves of both minerals and artificial ferric hydroxide gels, is to define as species the following only (Ref. 1-5):—

(A) Haematite α	Fe_2O_3 Rhombohedral.
(B) Haematite γ , or Maghemite	Fe_2O_3 Cubic, magnetic.
(C) Goethite (of which Limonite is the massive form)	$\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O} = \text{Fe}(\text{OH})\text{O}$ Orthorhombic. 0.92 : 1 : 0.64.
(D) Lepidocrocite	$\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O} = \text{Fe}(\text{OH})\text{O}$ Orthorhombic. 0.43 : 1 : 0.64.

The other five supposed species are either intimate intergrowths of A or B with C or D, or imperfectly analysed minerals in which undetermined Al_2O_3 has been weighed with and counted as Fe_2O_3 , and organic matter with H_2O ; or specimens carrying adsorbed and occluded water.

Of these alternatives probably the most serious cause of error is imperfect analysis, no proper search or allowance having been made in many cases for intimately admixed kaolin, halloysite and gibbsite. For this reason there is a need for the accumulation of a number of modern accurate analyses of these common minerals. Opportunity was therefore taken of analysing some very pure specimens of crystalline "hydrohaematite" received recently from Inglehope in the Darling Range south of Perth. The mineral forms the inner layer of hollow ovoid concretions found a few chains north of the railway siding. The concretions reach a foot or more in diameter. The outermost layer, averaging one centimetre in thickness, is composed of very cellular brown limonite. It is succeeded by a layer of dense brown to black iron ore of undetermined character. The innermost layer has a brilliant metallic lustre with mammillary surface, at right angles to which the mineral cleaves in a series of slightly curved and radiating faces with brilliant lustre typical of "goethite" and "hydrohaematite" elsewhere, and somewhat reminiscent of a series of tightly packed flowerbuds.

This mineral on analysis proves to agree with descriptions of "hydrohaematite." Its composition is:—

Hydrohaematite, Inglehope.

Fe_2O_3	Al_2O_3	Mn_2O_3	SiO_2	H_2O	Mg, Ca	Ti, V, P	Total	G
96.86	1.26	.19	.41	1.73	Nil	Nil	100.45	4.48

Analyst, D. G. Murray.

At first sight the molecular ratio of $\text{Fe}_2\text{O}_3/\text{H}_2\text{O}$ is 6.3/1.0, but if the Al_2O_3 and SiO_2 are first calculated as halloysite and gibbsite, half the water disappears, whilst the small remainder might well be present as occluded moisture or remnants of pre-existing goethite.

In view of what has been stated, the Inglehope mineral is to be considered as a pseudomorph of haematite after crystallised goethite, still retaining some small cores of unaltered goethite, and a little admixed halloysite (or kaolin) and gibbsite.

It is to be noted that Weiser and Milligan (⁴) recently found that ageing of the brown hydrated gel precipitated from solutions of ferric salts shows X-ray proof of the normal alpha-haematite after a few months in the cold, or after a few hours near 212° C.

References: (1) 1919, Posnjak & Merwin, Amer. Jour. Sci. 47, p. 311.

(2) 1925, Gaubert, Comp. Ren. Ac. Sci. 181, p. 869.

(3) 1929, Boehm, Zeit. Kryst. 68, p. 567-585.

(4) 1935, Weiser and Milligan, Jour. Phy. Chem. 39, p. 25-34.

(5) 1935, Goldsztaub, Bull. Soc. franc. Min. 58, p. 6-76.

(11)—PISANITE, RAVENSTHORPE, S.W.

Pisanite is a well defined monoclinic double salt bearing the same relationship to the isomorphous minerals melanterite, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ and boothite, $\text{CuSO}_4 \cdot 7\text{H}_2\text{O}$, that dolomite does to calcite and magnesite. Other isomorphous compounds co-crystallised in small proportions in some occurrences are the monoclinic forms (unknown as independent minerals) of the corresponding compounds of magnesium zinc and nickel, and the manganese salt occurring naturally as mallardite.

Pisanite is a greenish blue mineral, stable in moist air, such as is found in damp mine workings, its customary situation, but efflorescing superficially in dry air, to a white granular salt of less degree of hydration, probably the rather stable pentahydrate, as in a dessicator the water content is rapidly reduced by two molecules. On warming in air to a temperature of 100° C. disintegration sets in, not only by further dehydration, but by slow oxidation of the ferrous iron.

A unique cobaltiferous pisanite with an appreciable co-crystallisation of $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ (bieberite)⁶, was found in 1934 forming crusts on the timbers and walls of the abandoned Surprise C.M. (ML 114) at Ravensthorpe. It is in rather finely crystalline crusts a few millimetres thick as well as in small stalactites. It is translucent in thicknesses up to 5 mm. and is of a greenish blue colour, which could not be matched in Ridgway's index, the nearest approach being 43' i or k. This is the commonest tint, but there is a slight variation due probably to some specimens containing a little more or less copper than the normal amount. The mineral is readily soluble in cold water.

A preliminary analysis of a small fragment yielded CuO, 14.0; FeO, 12.1 per cent. Theory requires CuO, 14.11; FeO, 12.74 per cent. For a complete analysis some fragments of uniform and normal colour were

selected and kept in a vessel with a little moist cotton wool to avoid dehydration. The specific gravity of several of these fragments was shown to be 1.95. The results of the analysis were:—

Pisanite, Ravensthorpe.

	CuO	FeO	NiO	CoO	MgO	CaO	Al ₂ O ₃	SO ₃
Per cent	13.09	11.00	.16	.57	.97	.27	.39	28.52
Mols	1633	1531	21	76	240	48	38	3562

SiO ₂	Zn, Mn, As, Sb, Ti	H ₂ O (a)*	H ₂ O (b)	Total
.11	Nil	14.23	30.69	100.00
.18	—	7899	17034	—

Analyst, C. R. Le Mesurier.

* Water. (a) Loss in desiccator. (b) Remainder by difference.

The loss of water after 7 hours at 50° was 27.12 per cent., and an extra 0.60 vaporised at 100°, at which stage oxidation of FeO began to be apparent. The mineral then still contained 17.20 per cent. of water, or a little over 5 molecules out of 14.

Previous analyses of pisanite (1) to (6) have shown the presence of isomorphous magnesium in two cases (Leona Heights and Isabella, both U.S.A.) zinc in three cases (Huelva, Spain, and Rico and Bingham U.S.A.) manganese in one case (Huelva, Spain) and nickel in two cases (Lading, Austria, and Huelva, Spain). The presence of cobalt in the Ravensthorpe mineral is unique. It is interesting to note also the presence of nickel and magnesia, and the absence of zinc. Up to the present no zinc minerals have been detected at Ravensthorpe, but cobaltite occurs in small quantities in several of the copper-gold mines. The pisanite obviously originates in the oxidation of chalcopyrite intergrown with a little nickeliferous cobaltite and occurring in a shear zone in amphibolite, whence the magnesia.

No exact calculation of the molecular ratios can be made owing to the uncertainty regarding the form in which the lime and alumina occur. Allowing, however, small amounts of SO₃ and H₂O to be combined with them, the remaining ratios Cu + Ni + Co : Fe + Mg : SO₄ : H₂O come out very close to the theoretical ratios 1 : 1 : 2 : 14.

References: (1) 1923 Collins, Minl. Mag. 20, p. 32.

(2) 1927 Vavrinecz, Zeit, Kryst. 66, p. 167-8.

(3) 1929 (Abs. 1931) Vavrinecz, Minl. Abs. 4, p. 381-2.

(4) 1929 Doelter, Handb. der Mineralchem. 4 (2), p. 290-1.

(5) 1930 Hintze, Handb. der Mineralogie, 1 (3) p. 4375.

(6) 1933 Eckel, Amer. Minl., 18, p. 449-454.

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